DOCUMENT RESUME

ED 466 173 IR 021 244

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TITLE	Application of Mobile Agents in Web-Based Learning Environment.
PUB DATE	2001-06-00
NOTE	7p.; In: ED-MEDIA 2001 World Conference on Educational Multimedia, Hypermedia & Telecommunications. Proceedings (13th, Tampere, Finland, June 25-30, 2001); see IR 021 194.
PUB TYPE	Opinion Papers (120) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Computer Assisted Instruction; Computer Mediated Communication; Computer Uses in Education; Educational Environment; *Educational Technology; Foreign Countries; Information Systems; Internet; World Wide Web
IDENTIFIERS	New Zealand

ABSTRACT

Web-based learning environments are strongly driven by the information revolution and the Internet, but they have a number of common deficiencies, such as slow access, no adaptivity to the individual student, limitation by bandwidth, and more. This paper outlines the benefits of mobile agents technology, and describes its application in Web-based learning environments to improve the learning process. The TILE (Technology Integrated Learning Environment) project aims to provide an integrated system for the management, authoring, delivery, and monitoring of education at a distance. Mobile agents technology is being used in the implementation of the TILE adaptation mechanism. (Author/AEF)

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Application of Mobile agents in Web-based Learning environment

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Abstract: Web-base learning environments are strongly driven by information revolution and the Internet, but they have a number of common deficiencies, such as slow access, no adaptivity to individual student, limitation by bandwidth, and so on. This paper outlines the benefits of mobile agents technology, and describes its application in web-based learning environment to improve learning process. Mobile agents technology is being used in the implementation of the TILE adaptation mechanism, which the TILE project aims to provide an integrated system for the management, authoring, delivery and monitoring of education at a distance.

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1. Introduction

Intelligent Agents are one of the "hot" topics in Information Systems Research and Development at the moment. The last ten years have seen a marked interest in agent-oriented technology and a distinct trend has evolved to the research and development work on intelligent agents. This trend relates to the diversification in the types of agents being investigated and most popular types include user interface agents, information agents, multi agent system, mobile agent and so on.

The educational systems, especially the web-based learning environments, are becoming mainstream applications on the Internet. But these environments face some common deficiencies, which need to be resolved. Intelligent agents, and in particular, mobile agents, have huge potential to address those deficiencies. A number of research projects have been initiated to apply agent technology in web-based learning environments. But most of these research projects have used intelligent interface agents, which are usually static. In this paper, we shall demonstrate how mobile agents can address the problems that limit the potential web-base learning environment development.

2. Challenges for web-base learning environments

The information revolution has induced the boom of knowledge economy. This strong trend is supported by the updating technologically skilled workforce, which is achieved by lifelong learning, education in the workplace and distance education. Those are the prime factors driving the web-base education.

Institutions with long-standing involvement in distance education, such as the Open University in United Kingdom, are incorporating web-based elements in their instruction. Although Web-based course materials have advantages over conventional textbooks and lecture notes, they have a number of common deficiencies, such as access to course materials is slow; courseware does not adapt to individual students; the real time interaction between student and system is hard to achieve because of the connection unreliability and bandwidth limitations.

A number of attempts have been made to attack some of these problems, but solution to one problem often impedes solutions of the remaining problems. For example, InterBook (Brusilovsky et al., 1996) supports adaptivity and authoring, but all adaptation and page generation takes place at the central server, risking access delays. QuestWriter (Bogley et al., 1996) supports authoring, and has built-in client-side and servers side interactivity, but does not adapt presentations to individual students. ADE (Shaw et al., 1999) uses an animated pedagogical agent, who guides and assesses students, to develop an agent-assisted learning environment. The Adele agent basically belongs to an intelligent interface agent, which still concentrates on providing helps to students.

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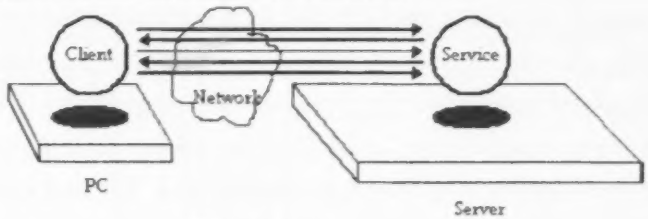
In general sense, a web-based learning environment should interact with the students, adapt to the needs of individual students, support interaction with teachers and other students, and be user-friendly to the authors. The emerging mobile agents technology is not only capable to facilitate these benefits but also attempts to address the problems mentioned above.

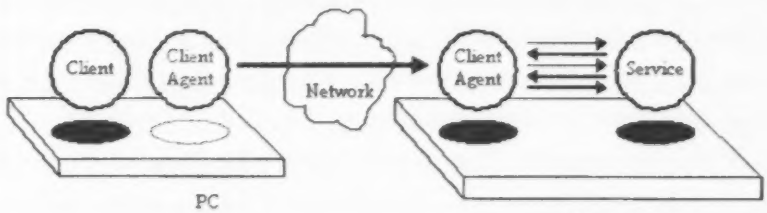
3. Motivation for using mobile agents

Although it is possible to propose an alternative, based on an existing technology, to almost every mobile agent-based function (Chess et al., 1995), in certain cases mobile agents have significant advantages over conventional approaches at the design, implementation and execution stages. The motivation for using mobile agents stems from following anticipated benefits:

- *Efficiency and reduction of network traffic:* Mobile agents consume fewer network resources since they move the computation to the data rather than the data to the computation. Also mobile agents can package up a conversation and ship it to a destination host, where the interactions can take place locally, so network traffic is reduced (figure 1).
- *Asynchronous autonomous interaction:* Tasks can be encoded into mobile agents and then dispatched. The mobile agent can operate asynchronously and independent of the sending program.
- *Interaction with real-time entities:* Real-time entities require immediate responses to changes in their environment. Controlling these entities from across a potentially large network will incur significant latencies. Mobile agents offer an alternative to save network latency.
- *Local processing of data:* Dealing with vast volumes of data when the data is stored at remote locations, the processing of data over the network is inefficient. Mobile agents allow the processing to be performed locally, instead of transmitting the data over a network.



Client-server



Mobile Agent approach

Figure 1. Client-server paradigm vs. Mobile Agent approach.

- *Support for heterogeneous environments:* Both the computers and networks on which a mobile agent system is built are heterogeneous in character. As mobile agent systems are generally computer and network independent, they support transparent operation.
- *Convenient development paradigm:* The design and construction of distributed systems can be made easier by the use of mobile agents. Mobile agents are inherently distributed in nature and hence are natural candidates for such systems.

4. Application of mobile agents technology in web-base learning environment

After examining the benefits of mobile agents, and considering the limitations of web-based learning environments, it becomes clear how mobile agents technology addresses those limitations very naturally. We discuss below how mobile agents can improve web-based learning environment.

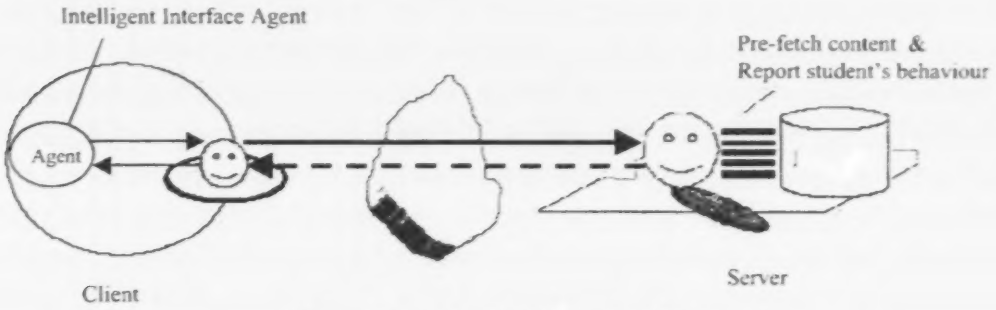


Figure 2. Scenario of mobile agent working

- In a web-base learning environment, as shown in figure 2, mobile agents can be used to pre-fetch the domain content that will be requested shortly by the student, and report student's performance to the central server. This pre-fetch process is based on real-time analysis of the student's behavior, and calculation of the probability of a request. Each student behavior, as they work through the web-based learning system, can be monitored and recorded by an intelligent interface agent, which runs on the student computer. Depending on the state of the network, an immediate request or a reservation can be fulfilled by the mobile agent. In this way, end-to-end quality of the service can be improved for the delivery of distributed multimedia material, such as that represented by distance education. This agents technology avoids unnecessary networking delays, cope the bandwidth limitation and adapt the representations to students, based on the student performance.

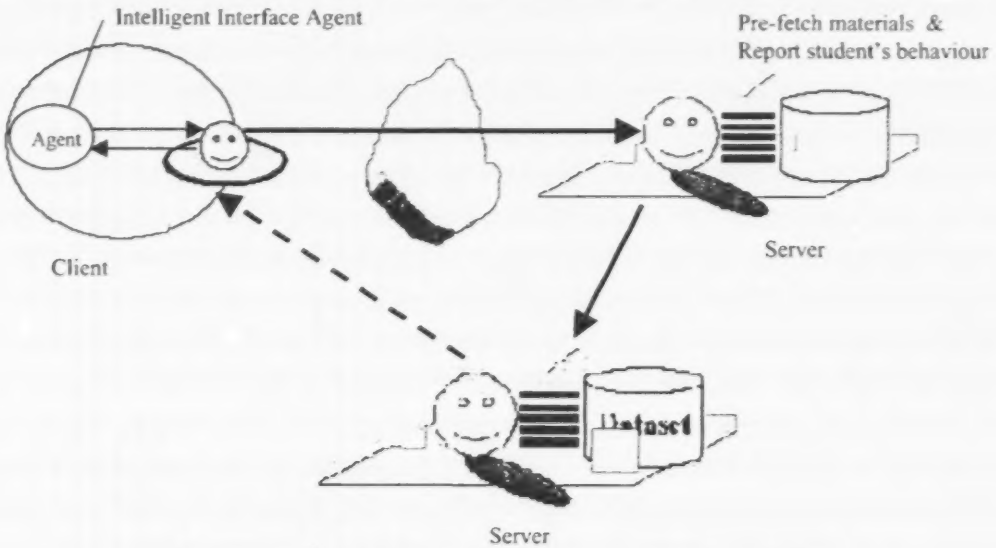


Figure 3. Scenario of mobile agent moving around distributes systems

- In terms of mobile users, portable-computing devices such as laptops, palmtops, and electronic books will access web-based learning environments. These devices have unreliable, low-bandwidth, high-latency telephone or wireless network connections. Mobile agents will be essential tool for allowing such access.

- Mobile agents offer application developers a new programming paradigm with higher-level abstraction and unified "process" and "object". In terms of scalability of system and easy authoring, these features of mobile agents offer a flexible and effective philosophy on learning environment development, design, and scalability.
- In the future, web-based learning environments can share resources through different systems, as shown in figure 3. Both the computers and networks on which web-based systems are built are also heterogeneous in character. As mobile agent systems are generally computer and network independent, they support distributed systems and resources sharing.
- On another note, web-based learning environments are ideal test beds for mobile agents technology. Till now, electronic commerce has been treated as the only important target for mobile agents technology. Money is involved, so security is a key factor for agent technology. There are three types of security: agent-agent security, host-agent security, and agent-host security. Existing techniques can be successfully applied to protect agents from malicious agents, and hosts from malicious agents, but it is currently very hard to protect the agents from malicious hosts due to the possibility of the host changing the programming code of agent for some vested interests. This factor is one of main obstacle affecting mobile agents applications in the real world. However, in education sector, the agent-host security is not as important as in electronic commerce. This makes the web-based learning environments as the most suitable test bed for mobile agents technology.

Mobile agents technology is being applied in the TILE project. Following section gives brief introduction of TILE before describing the application of mobile agents.

6. Application of mobile agents for student adaptivity in TILE

The Technology Integrated Learning Environment project (TILE) aims to provide an integrated system for the management, authoring, delivery and monitoring of education at a distance. Its architecture gives a modular framework for the inclusion of a range of tools to achieve the project's goals. TILE can be compared to a computer aided software engineering (CASE) tool but for the development of on-line education. It supports the planning of syllabi and courseware, the tracking of development by staff, the reuse of course-ware modules and (if necessary) any auditing of royalties. Finally and perhaps most importantly it provides a means by which the educational web sites are built. One of the main aims of the TILE is to provide adaptive learning environment to the students. The adaptation in the system requires consideration of following criteria (Kinshuk et al., 1999):

(a) adaptation with respect to current domain competence level of the learner;
(b) suitability with respect to domain content; and
(c) adaptation with respect to the context in which the information is being presented.

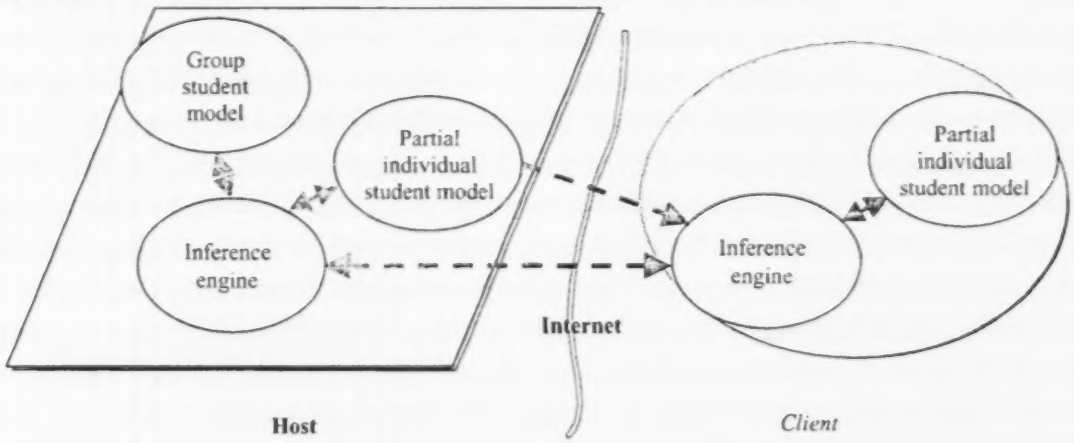


Figure 4. Adaptation mechanism in TILE environment

The fulfillment of these criteria requires the development of student model that captures the interactions of student with the system to extract information about student's competence level for various domain concepts and tasks represented in the system. TILE environment benefits from the collaborative learning on the web by having two separate student models:

1. *Individual student model*, which serves an individual student and contains the detailed information about particular student's domain competence level, preferences, interaction information and other relevant details; and
2. *Group student model*, which generalises various attributes over a number of students and attempts to classify students in various categories (for various attributes).

This two-step modelling enables the system to provide adaptation at different granularity, and also refines default assumption of the system towards new students.

The learning process in the TILE environment also benefits from the client-server approach, which has been extended to the adaptation process. Consequently, the student model is divided into host and client bases. The host base contains the group student model, and partial individual student model, whereas client base contains only individual student model. This approach serves a number of purposes. First of all, it allows the system to be much more flexible, particularly in the web-based environment, where connectivity between host and client is not always guaranteed, and the quality of the connection often suffers from traffic congestion. The client side student model facilitates adaptivity even in offline mode, whereas host side student model allows adaptivity based on new information available from the domain experts and better adaptation procedures resulting from group student model. Figure 4 shows the schemata of the adaptation mechanism in the TILE environment.

Mobile agents technology is being used in the implementation of the TILE adaptation mechanism. Figure 5 describes the implementation of mobile agents technology in the adaptation mechanism.

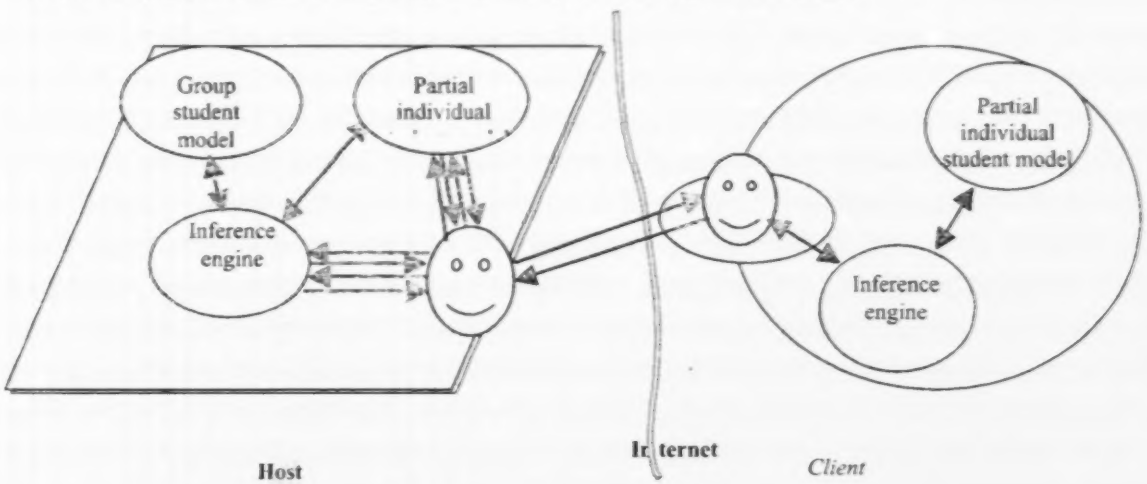


Figure 5. Implementation of mobile agents technology in adaptation mechanism.

As seen in figure 5, a mobile agent interacts with client side inference engine to pick up data, which relies on individual student model at client side. Then mobile agent moves to the host (or server) side. At host side, mobile agent performs all the processes needed, such as updating the partial individual student model based on summary of client side student model (based on the data brought by mobile agent), interacting with group student model to determine if that student model also needs to be updated. After mobile agent finishes all actions at host side, it gathers all the information it needs, and returns to the client side. Then it updates the client side individual student model. This mobile agent approach works even in the intermittent connectivity between client and host because mobile agent can be dispatched when the connection is available and then the agent works autonomously without requiring continuous connection.

7. Conclusion

There is a strong case in favour of the use of mobile agents in many Internet applications. Moreover, there is a clear evolutionary path that will take us from current technology to widespread use of mobile agents within the next few years. Once few technical challenges are met and few pioneering web-based applications start using mobile agents technology, we believe, the use of mobile agents will expand rapidly. TILE project is one such step in that direction.

A number if research issues are still to be resolved. For example, besides building mobile agent, we also have to provide environment for mobile agent. Although some mobile agent systems, such as Bee-gent, come with wrappers, they are still quite limited. But we hope, mobile agents technology will open a new interesting research area in the web-base education, where traditional approaches are proving fruitless due to severe limitations imposed by the existing technology.

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